Whipple Creek

Water Quality and Stream Health
Data Summary

Clark County Public Works
Water Resources Section

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Purpose and Scope

This report summarizes available water quality, benthic macroinvertebrate, and physical habitat data from Whipple Creek in Clark County, Washington. It is intended to provide baseline stream health information and to better inform the process of developing the Whipple Creek Watershed Projects Plan (WCWPP). The WCWPP will utilize a variety of stream and watershed information to address existing and future stormwater management issues.

General stream health is characterized by a series of multi-metric indices as well as several individual metrics. A description of applicable water quality criteria is included, along with discussions of beneficial use impacts, likely pollution sources, and possible implications for stormwater management planning. The final section includes an examination of gaps in existing monitoring data and suggests potential projects that may be considered to address those gaps.

Water Quality

Applicable Water Quality Criteria

In 2003, the Department of Ecology proposed numerous revisions to Washington's water quality standards. The revised standards are currently under review by US EPA and have been only partially approved. For a full explanation of current water quality standards see the Ecology website at: www.ecy.wa.gov/programs/wq/swqs/rev_rule.html.

Pending EPA approval of the proposed revisions, the existing 1997 version of the standards is to be used for temperature, dissolved oxygen, turbidity, total dissolved gas, and pH criteria. Aquatic life uses and anti-degradation policies, among other topics, are also to be interpreted based on the 1997 standards. The 2003 standards are to be applied for Recreational (includes bacteria criteria), Water Supply, and Miscellaneous uses, as well as for toxics and aesthetics, lake nutrient criteria, and various other topics.

Under the 1997 standards, Whipple Creek is a "Class A" waterbody and is expected to meet or exceed the requirements for all or substantially all uses, including: water supply; stock watering; salmonid migration, rearing, spawning, and harvesting; wildlife habitat, and; recreation, including primary contact recreation, sport fishing, boating, and aesthetic enjoyment.

Under the 2003 standards, Whipple Creek is to be protected for "primary contact recreation" as well as narrative criteria for toxics and aesthetics.

Table 1 summarizes currently applicable criteria for Whipple Creek . With the exception of toxics, these characteristics are included in or addressed by the Whipple Creek dataset.

303(d) Listing

Ecology recently finalized the 2002/2004 303(d) list of impacted waters for submittal to US EPA. Based on Clark County Water Resources data, Whipple Creek in the vicinity of Sara (intersection of NW 41st Ave and NW 179th Street) is listed as water quality impaired for fecal coliform bacteria, and as a "water of concern" for stream temperature. The 303(d) listing for bacteria places Whipple Creek on the list of waters for which Ecology is required to generate a Total Maximum Daily Load (TMDL), also known as a Water Cleanup Plan.

Table 1. Applicable water quality criteria for Whipple Creek (May 2005)

Characteristic	1997 standards	2003 standards
Temperature	18 °C (64 °F)	
Dissolved Oxygen	8.0 mg/L	
Turbidity	not to exceed 5 NTU over background when background is 50 NTU or less	
pH	6.5 – 8.5 units	
Fecal coliform bacteria		Geometric mean fecal coliform concentration not to exceed 100 colonies/100mL, and not more than 10% of values exceeding 200 colonies/100mL.
Aesthetics		Aesthetic values must not be impaired by the presence of materials or their effects… which offend the senses of sight, smell, touch, or taste
Toxics		Toxic, radioactive, or deleterious material concentrations must be below those which have the potential…to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health

Source: Washington Department of Ecology (www.ecy.wa.gov/programs/wq/swqs/rev_rule.html)

Clark County Stream Health Report

In 2003, Clark County Water Resources compiled available data and produced the first county-wide assessment of general water quality.

Whipple Creek was assessed in conjunction with Gee, Flume, and Allen Canyon creeks as the West Slope Watershed. Based on a limited available dataset including fecal coliform bacteria, general water chemistry (temperature, pH, and dissolved oxygen), and benthic macroinvertebrate scores, overall stream health in the West Slope Watershed scored in the poor to very poor range. Though data were available for only 10% of the stream miles in the watershed, a simple land-use model predicted poor stream health in the remainder of the watershed.

The entire 2003 Stream Health Report may be viewed on the county website at http://www.clark.wa.gov/water-resources/stream.html.

Current Water Quality

The following water quality summary is based on monthly data collected between May 2002 and December 2004 at Whipple Creek station WPL050 (see Figure 1), located just downstream of the Sara intersection (NW 179th St and NW 41st Ave). The data are presented in terms of a multi-characteristic water quality index, followed by summaries of several individual characteristics. Hourly water temperature data collected from approximately May through September during 2002, 2003, and 2004 are also included.

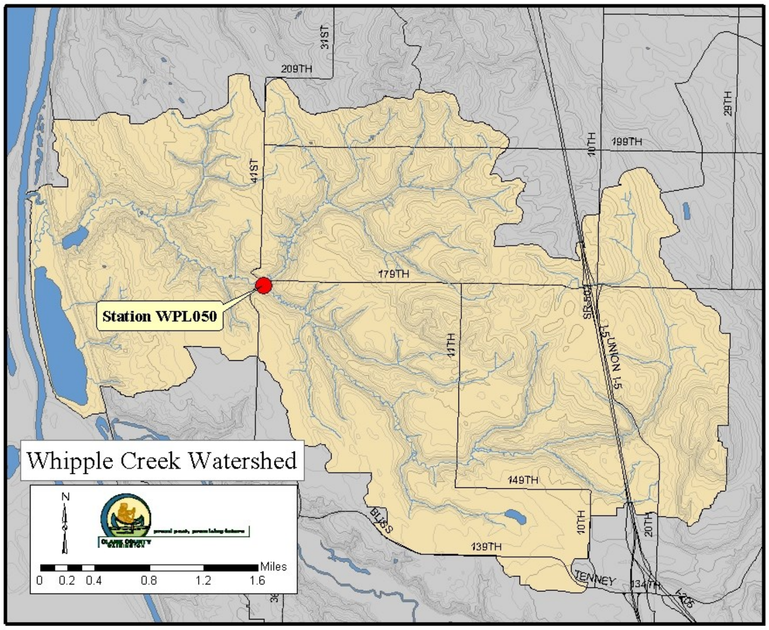

Figure 1. Whipple Creek Watershed and location of monitoring station WPL050.

<u>Oregon Water Quality Index (OWQI)</u>
The OWQI was developed by the Oregon Department of Environmental Quality (ODEQ) as a way to improve understanding of water quality issues by integrating multiple characteristics and generating a score that describes water quality status (Cude, 2001). It is intended to provide a simple and concise method for expressing ambient water quality.

The OWQI integrates eight water quality variables: temperature; dissolved oxygen; biochemical oxygen demand; pH; ammonia + nitrate nitrogen; total phosphorus; total solids; and fecal coliform. For each sampling event, individual subindex scores and an overall index score are calculated. Overall index scores are aggregated into low flow (June – September) and high flow (October – May) seasons and a seasonal mean value is then calculated.

Index scores are categorized as follows:
very poor = 0 to 59; poor = 60 to 79; fair = 80 to 84; good = 85 to 89, and; excellent = 90 to 100.

Figure 2 shows seasonal mean OWQI scores for station WPL050 from 2002 to 2004. The overall average OWQI score from 2002 through 2004 is also included.

OWQI scores since 2002 rank consistently in the poor category. Individual sub-index scores for total solids, nitrogen, and total phosphorus were consistently poor, while scores for fecal coliform ranged from very poor to excellent and showed wide seasonal variations. Sub-index scores for temperature, dissolved oxygen, and pH were consistently good to excellent.

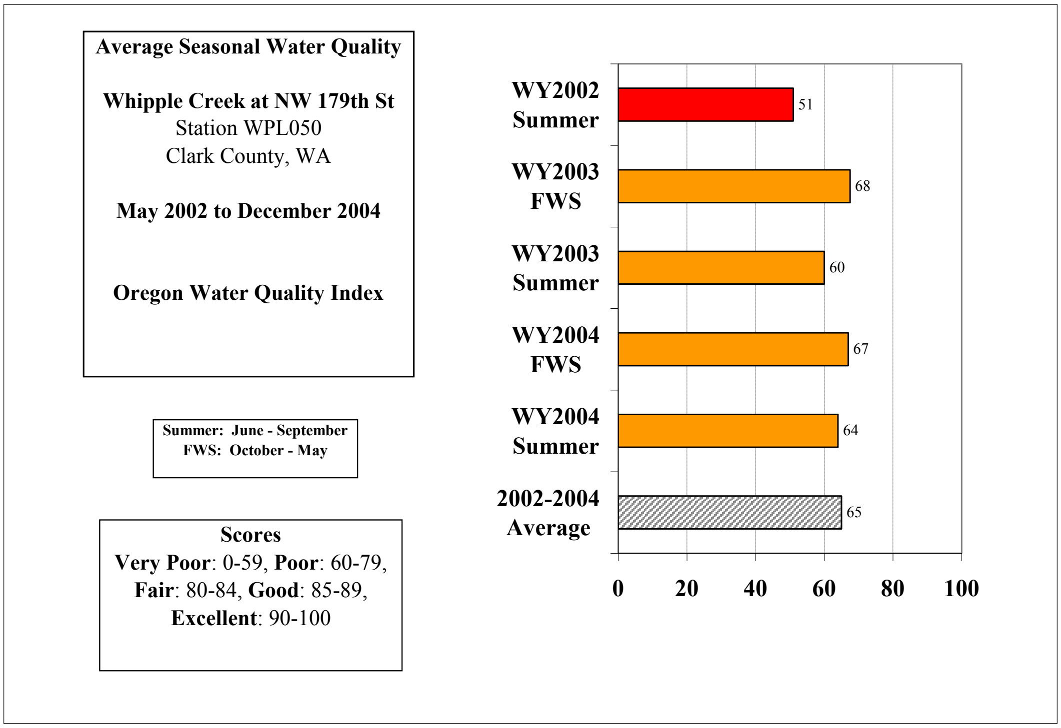

Figure 2. Average seasonal water quality, Whipple Creek station WPL050. Oregon Water Quality Index.

<u>Fecal coliform bacteria</u>

Figure 3 shows seasonal geometric mean fecal bacteria values from May 2002 through December 2004. Based on 12 sampling events, the summer (June – September) geometric mean at station WPL050 was 688 cfu/100mL. Based on 20 sampling events, the FWS (October – May) geometric mean was 216 cfu/100mL. Geometric mean values for both seasons exceed the state criterion of 100 cfu/100mL. One hundred percent of summer samples also exceeded the single-sample criterion of 200cfu/100mL, while 60 percent of FWS samples exceeded this criterion. Individual samples ranged from 30 cfu/100mL to 1600cfu/100mL.

<u>Nutrients</u>

Ecology has not established nutrient criteria for Washington streams. US EPA suggests a total phosphorus criterion of 0.100 mg/L for most streams, and 0.050 mg/L for streams which enter lakes (EPA, 1986). EPA nitrate criteria are focused on drinking water standards and are not generally applicable to aquatic life issues.

Phosphorus and nitrogen in excess may contribute to elevated levels of algal or plant growth, especially in slower moving, low gradient streams or in downstream water bodies.

Total phosphorus samples from WPL050 between May 2002 and December 2004 ranged from 0.043 mg/L to 0.163 mg/L, and seventy-five percent of samples exceeded the EPA criterion. Total phosphorus concentrations typically vary seasonally in many locations; however, seasonal median values in Whipple Creek are quite similar:

- Summer median = 0.127 mg/L
- FWS median = 0.112 mg/L

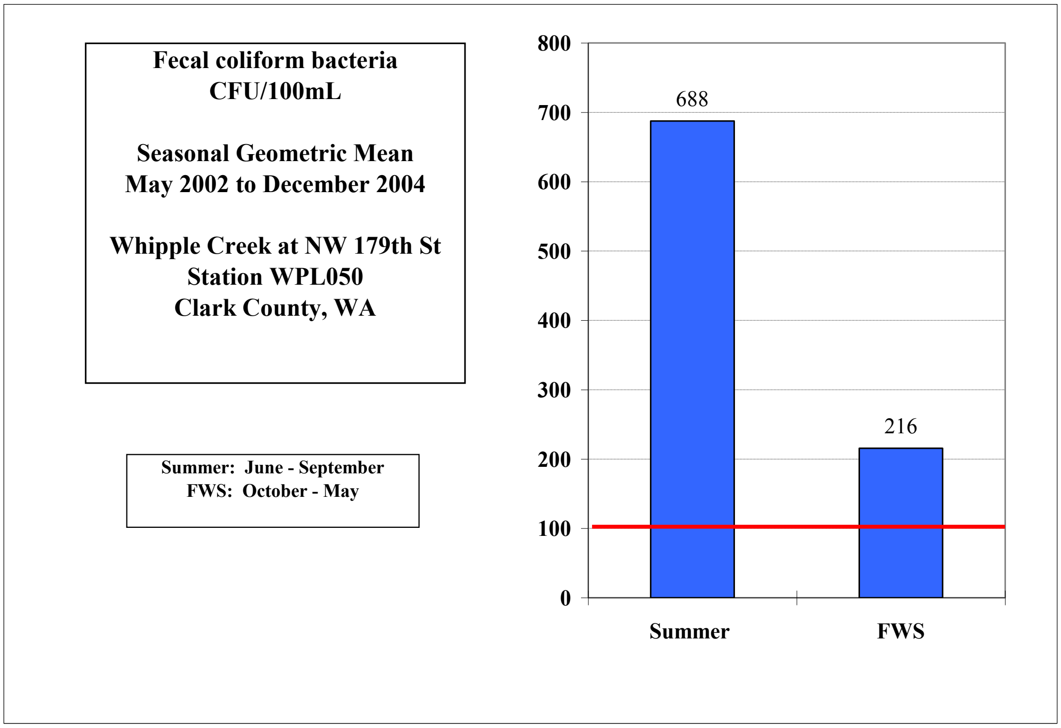

Figure 3. Seasonal geometric mean fecal coliform, Whipple Creek station WPL050, May 2002 through December 2004.

Turbidity

It is difficult to establish an exact background turbidity level for Whipple Creek because no data exist from a time when Whipple Creek was not impacted by human activities. However, based on data from the least-impacted streams monitored by Water Resources, we estimate that natural background turbidity in most Clark County streams would have been in the range of 0.5 to 2 NTU. Based on this estimate, the turbidity criterion for Whipple Creek is between 5.5 and 7 NTU.

Since August 2001, the median of 40 turbidity samples at WPL050 is 7.7 NTU, with individual samples ranging from less than 5 NTU to 200 NTU. Turbidity varies somewhat seasonally:

- Summer median = 6.6 NTU
- FWS median = 9.8 NTU

At the WPL050 station, Whipple Creek often has a hazy, slightly milky appearance during baseflow conditions, which contributes to slightly elevated routine turbidity readings. Higher turbidity readings in the 20-40 NTU range are common during storm events. Extremely high turbidity values often indicate a specific sediment source during rainfall events. The highest recorded value in Whipple Creek was 200 NTU in November 2003. The source of this event was an overwhelmed and malfunctioning stormwater facility draining a large area of exposed soil during construction of the Whipple Creek Place subdivision, approximately one mile upstream of the monitoring station.

Stream temperature

In addition to the routine monthly temperature readings which are incorporated into OWQI calculations, continuous temperature loggers recorded hourly temperature values between May and October during 2002, 2003, and 2004. Continuous readings provide a more complete picture of temperature dynamics than monthly grab samples.

Table 2 summarizes the continuous temperature data. The seasonal maximum temperature represents the highest recorded value during the deployment, and is the value used to compare with the 1997 criterion. Seasonal Max ΔT is the maximum daily temperature fluctuation. The 7-Day average maximum value is the maximum of the 7-day moving average of daily maximum temperatures. The 2003 standards under EPA review will utilize this metric to determine temperature compliance. The Days >64 value records the number of days on which the *daily* maximum temperature exceeded the 64° F criterion.

Table 2. Seasonal maximum temperature, temperature change, and 7-day moving average

Seasonal Maximum		Seasonal Max ΔT		7-Day averages			
Date	**Value**	**Date**	**Value**	**Date**	**Maximum**	**ΔT**	**Days >64 F**
7/22/02	**67.5**	7/5/02	5.4	7/23/02	66.1	3.7	23
7/30/03	**69.1**	6/25/03	5.9	7/29/03	66.9	4.6	47
7/24/04	**71.2**	6/16/04	6.0	7/22/04	69.0	4.2	61

Stream temperature at WPL050 exceeded the state criterion in each year monitored, and seasonal maximums increased each year. Due to the negative effects of chronic high temperatures on salmonids and other cold-water biota, the amount of time spent out of compliance is also of interest. Figure 4 shows the number of days on which temperatures exceeded the 64° F criterion, and the average number of hours spent above 64° F on those days.

The number of days out of compliance increased fairly dramatically each year, from 23 days in 2002 to 61 days in 2004. This increase is probably attributable to differences in ambient air temperatures and stream flow between years. Figure 4 also indicates that when exceedences occur Whipple Creek biota are subject to temperatures in excess of 64° F for a substantial part of the day.

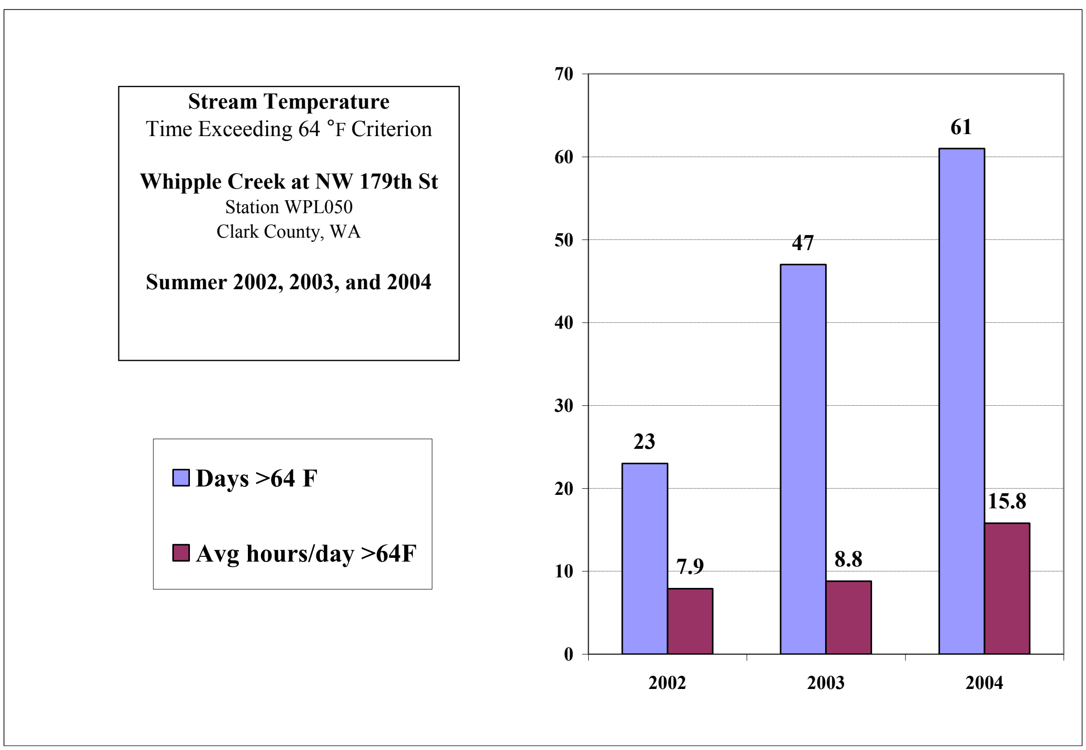

Figure 4. Time exceeding 64° F water temperature criterion, 2002 – 2004, Station WPL050.

Impacts to Beneficial Uses

General water quality in Whipple Creek is poor according to the OWQI, and listed beneficial uses are directly impacted by several water quality characteristics, including: fecal coliform bacteria, temperature, turbidity, total phosphorus, and total solids.

Observed levels of these characteristics may have negative impacts on the beneficial uses of: recreation and aesthetic enjoyment; salmonid rearing and spawning, and; wildlife habitat. Table 3 at the conclusion of this section summarizes the primary water quality impacts to beneficial uses in Whipple Creek, and probable sources of the observed impact. Beneficial use impacts and likely sources are discussed in more detail below.

<u>Recreation and aesthetic enjoyment</u>

Fecal coliform bacteria

Primary contact recreation is impacted by consistently elevated counts of fecal coliform bacteria which indicate the possible presence of pathogens. Although water contact may take place year-round, elevated bacteria counts are of particular concern during the summer months when the majority of water contact recreation occurs. Although Whipple Creek has no developed swimming or wading areas, it is likely that some local residents, particularly children, utilize the creek for recreation. If so, there is some risk of illness due to bacterial contamination.

Water quality data suggest that fecal coliform issues in Whipple Creek stem from multiple sources. Human sources are the primary concern and represent the greatest risk of serious health impacts such as hepatitis; however, non-human sources also carry risks. For instance, beavers and other wildlife may carry the intestinal parasite <u>*Giardia*</u> <u>*lamblia*</u> which is spread through feces and causes a variety of intestinal symptoms in humans.

Elevated bacteria levels in summer (June-September) baseflow are likely being introduced through direct connection to sewage and animal wastes. Localized septic tank or sanitary sewer leaks enter the stream directly through shallow groundwater seeps and may also enter the storm sewer system. Past storm sewer screening activities in Whipple Creek noted several locations where baseflow being carried by storm sewers had elevated bacteria counts.

Non-human sources in summer baseflow include direct wildlife and livestock access. The 2005 Whipple Creek Stream Assessment indicated Whipple Creek supports a large amount of beaver activity. Waterfowl were also present in moderate numbers in some reaches and could be a contributing factor. In the assessed reaches, little evidence of direct livestock access was encountered and no direct access was observed. However, where evidence was found, it appeared that animals were present seasonally and primarily during the warmer months. Therefore, seasonal livestock access may be contributing to elevated summer bacteria concentrations.

Stormwater is easily overlooked as a potential source of bacteria during the summer, since rainfall is relatively infrequent. However, an examination of June through September bacteria data indicate that some of the highest dry-season bacteria concentrations have occurred during or shortly after rain events. Although dry-season bacteria concentrations are consistently elevated regardless of rainfall, the influence of stormwater should be recognized as a significant source of bacteria in Whipple Creek during the summer.

Due partly to greater dilution by higher volumes of baseflow, routine bacteria concentrations are often lower during the Fall/Winter/Spring (FWS) time period (October-May); however, total bacteria *loads* may actually be higher during this time due to the additional stream volume.

Additionally, bacteria concentrations are often higher during FWS storm events as a wide range of non-point sources contribute bacteria in amounts high enough to overcome dilution effects.

FWS bacteria sources may include all of the summer sources listed above as well as increased influence from sources that require surface runoff to transport bacteria to streams. Pet waste, manure storage, livestock confinement area runoff, and wildlife waste are among sources that enter streams through the storm-sewer system or by direct overland runoff. Though limited in number, the 2005 Whipple Creek Stream Assessment noted the presence of some hobby farms with small numbers of livestock, primarily in the headwater areas of Packard Creek and Whipple Creek.

Septic and sanitary sewer leaks can be an increased problem during FWS due to increased runoff and higher groundwater levels. Studies also suggest that fecal coliform bacteria can survive and reproduce in sediments on stream bottoms and in storm sewers. During storm events, these bacteria may be re-suspended and can increase concentrations above levels that would occur due to runoff alone.

Turbidity and solids
Aesthetic enjoyment may be limited by high turbidity. Whipple Creek often exhibits a milky, hazy appearance near station WPL050, and high turbidity during rain events may result in a condition resembling chocolate milk.

The primary sources of turbidity in Whipple Creek are probably erosion-related. Both off-site erosion (development, agriculture, recreational vehicle use) and in-stream erosion (bank scour, slumping, re-suspension of sediments during high flows) likely contribute significantly to the elevated turbidity during rain events. Septic or sewer leaks entering Whipple Creek through groundwater seeps may contribute to the milky or opaque appearance during baseflow conditions. Additionally, the elevated total phosphorus levels observed at station WPL050 has the potential to increase turbidity by contributing to excessive plant and algae growth, especially in ponded areas.

Total phosphorus (TP)
Currently, despite high nutrient levels, algae growth does not appear to contribute greatly to observed turbidity. However, the downstream impacts of high phosphorus concentrations may be more significant than local effects. High nutrient input from Whipple Creek may be contributing to observed blue-green algal blooms in Lake River, and also in Vancouver Lake (due to tidal influence). Once the high-nutrient water enters these slow-moving water bodies, the nutrients are readily available for utilization by plants and algae. Elevated nutrient levels in Vancouver Lake have contributed to potentially toxic algal blooms during recent summers, forcing lengthy closure of swimming areas.

The consistently elevated TP concentrations year-round indicate that a variety of sources are contributing at different times. Sources in Whipple Creek include groundwater contributions, human or animal waste, and erosion of soils with high clay content. These sources are transported to the stream through groundwater movement as well as through the storm sewer system, overland runoff, and direct animal access.

Elevated summer TP stems primarily from sources carried by groundwater seeps. Although groundwater in the Whipple Creek watershed tends to have high TP concentration (Turney, 1990), naturally elevated concentrations stemming from the underlying geology are very likely augmented by nutrients from fertilizers, leaking septic tanks and sewer infrastructure, wildlife, and direct livestock access.

Similar to bacteria, winter TP concentrations can be low or high depending on the amount of baseflow dilution and the impact of additional sources carried by storm sewers and overland runoff.

<u>Salmonid rearing and spawning</u>

Water temperature

Water temperature may be a significant water quality impediment to salmonid use in Whipple Creek. In particular, elevated temperatures have a detrimental impact on salmonid rearing. Migration and spawning tend to occur during cooler times of year, but juveniles are exposed to elevated summer temperatures during rearing.

Temperature-related impacts to salmonids begin to occur at stream temperatures greater than 64°F. Impacts include: decreased or lack of metabolic energy for feeding, growth or reproductive behavior; increased exposure to pathogens; decreased food supply; and increased competition from warm-water tolerant species (ODEQ, 2004 draft).

Although Whipple Creek is not among the warmest streams monitored by Water Resources, summer temperatures regularly exceed 64°F and suggest that temperature moderation will be a necessary component in any plan to recover fish populations.

Solar radiation is the primary driver of water temperature. The susceptibility of the stream to solar radiation is influenced by several factors including stream flow, canopy cover (shade), ponds, and the extent of groundwater influence.

Whipple Creek has relatively good riparian canopy cover throughout much of the watershed, though many areas do receive direct solar radiation and would benefit from riparian enhancement. A large number of ponds were noted during the 2005 Whipple Creek Assessment. Both beaver ponds and man-made ponds are common and likely contribute significantly to elevated temperatures. Below average summer stream flows over the past several years have made the stream more susceptible to temperature impacts.

Given the relatively dry summers in the Pacific Northwest, stormwater systems generally should not be a major factor in elevating summer temperatures. In some cases storm sewers may even contribute cool water in the form of piped baseflow. However, urban runoff from summer storms can cause stream temperatures to spike well above the criterion for a short period of time. While never observed directly in Whipple Creek, impacts of this type have been noted in nearby Cougar Creek, an urbanized subwatershed in Salmon Creek.

Turbidity and solids

Elevated turbidity and total solids are also a significant concern. Turbid water may limit foraging ability and indicate the presence of fine silt that clogs gills and spawning beds. Sedimentation of suspended solids loads compromises gravel spawning areas, smothers eggs, and impacts food availability by suppressing benthic macroinvertebrate populations. The available water quality data and high level of substrate embeddedness (see habitat section) suggest Whipple Creek carries a higher than desirable load of fine silt and sediment.

Total solids are composed of dissolved and suspended fractions. The dissolved fraction includes calcium, chloride, nitrate, phosphorus, iron, and other ions and particles. Suspended solids include silt, clay, algae, and other particulate organic matter.

The dissolved fraction affects the water balance in the cells of aquatic organisms; elevated concentrations make it more difficult to maintain proper cell density and function. The suspended fraction affects water clarity and sedimentation, and may serve as a carrier for toxics. High suspended solids will increase turbidity, decreasing light penetration and photosynthesis. High total solids also contributes to temperature issues by causing water to heat up more rapidly and hold more heat Primary sources of total solids include sewage, fertilizers, road runoff, and soil erosion (www.epa.gov/volunteer/stream/vms58.html).

Wildlife habitat

Water quality impacts to non-fish wildlife habitat stem primarily from the same issues noted above. Sedimentation, elevated water temperatures, and increasing total phosphorus concentrations may impact other wildlife species by modifying habitat structure and availability.

Implications for stormwater management

Table 3 lists the primary known water quality concerns and potential solutions for each. Solutions listed in bold indicate areas where Clean Water Program activities can have a positive impact. It should be noted that Clean Water Program activities, though important, are not likely to achieve water quality improvement goals on their own. Other county departments, local agencies, and the public must all contribute if water quality is to be improved.

Among the CWP activities most likely to have a positive impact on water quality are:

- effective stormwater system designs, retrofitting, and maintenance
- source detection and removal projects; and
- public education programs

Stormwater system design, retrofitting, and maintenance include a range of activities that can address specific pollutants of concern. Source detection and removal projects help eliminate specific contributions of pollutants. Education programs, though they rarely have a direct impact on water quality, are a critical element in modifying behavior and promoting better public stewardship of water resources.

Table 3. Known water quality concerns, sources, and solutions for Whipple Creek

Characteristic	Beneficial Use Affected	Potential WC Sources	Mechanism	Solutions (bold indicates direct Clean Water Program involvement)
Fecal coliform bacteria	Primary contact recreation	failing septic systems	groundwater seeps storm sewers	**Storm sewer screening for source identification and removal** **Education programs** **Storm water facility designs/retrofits to optimize bacteria reduction (see Schueler, 1999)** Agricultural Best Management Practices Septic and sanitary sewer system inspection and maintenance
		sanitary sewer leaks	groundwater seeps storm sewers	
		livestock, pets, wildlife	overland runoff storm sewers direct access	
Water temperature	Salmonid rearing	vegetation removal	direct solar radiation	**Stormwater infiltration to increase baseflow** **Streamside planting/vegetation enhancement** **Education programs** Pond removal or limitation
		ponds	direct solar radiation stagnation	
		low summer flows	decreased resistance to thermal inputs	
Turbidity	Salmonid spawning and rearing; Aesthetic enjoyment	erosion *(development projects; land clearing; cropland; impervious surfaces; channel erosion)*	overland runoff storm sewers channel dynamics	Erosion control regulations **Storm sewer system cleaning and maintenance** **Storm water facility designs/retrofits to optimize settling and removal of suspended silt/clay** Agricultural Best Management Practices **Stream bank stabilization/rehabilitation** **Storm water outfall/facility retrofits to reduce flow-induced channel erosion**
		algae	in-stream growth due to excess nutrients	
Total phosphorus	Aesthetic enjoyment	natural groundwater	groundwater seeps	Erosion control regulations Septic system inspections and maintenance Sanitary sewer leak identification and removal **Storm sewer system cleaning and maintenance** **Storm water facility designs/retrofits to optimize settling and removal of suspended silt/clay** Agricultural Best Management Practices **Education programs (reduced fertilizer use)**
		fertilizers	overland runoff storm sewers	
		erosion	(see turbidity)	
		livestock, pets, wildlife	(see bacteria)	
		failing septic systems	(see bacteria)	
		sanitary sewer leaks	(see bacteria)	
Total solids	Salmonid spawning and rearing; Aesthetic enjoyment	same as turbidity, plus:		same as turbidity, plus: **Education programs** Septic system inspections and maintenance Sanitary sewer leak identification and removal
		failing septic systems	(see bacteria)	
		sanitary sewer leaks	(see bacteria)	
		fertilizers	(see phosphorus)	

Benthic Macroinvertebrates

Water Resources collects benthic macroinvertebrates annually at station WPL050. The bugs are preserved and submitted to a professional laboratory for taxonomic identification and enumeration. Data are available at WPL050 for 2001, 2002, and 2004.

Benthic Index of Biological Integrity

Water Resources utilizes the widely applied Benthic Macroinvertebrate Index of Biological Integrity, or B-IBI (Karr, 1998), to measure the health of streams based on the macroinvertebrate population.

Karr's B-IBI score is the sum of ten metric scores that measure various aspects of stream biology, including tolerance and intolerance to pollution, taxonomic richness, feeding ecology, reproductive strategy, and population structure. Each metric was selected because it has a predictable response to stream degradation. For example, stonefly species are often the most sensitive to disruption and will be the first to disappear from a stream as human disturbance increases.

The raw data value for each metric are converted to a score of 1, 3, or 5, and the ten individual metrics are added to produce an overall B-IBI score ranging from 10 to 50. Scores from 10-24 indicate low biological integrity, from 25-39 indicate moderate integrity, and greater than 39 indicate high biological integrity.

Figure 6 includes the overall B-IBI scores from WPL050 in 2001, 2002, and 2004.

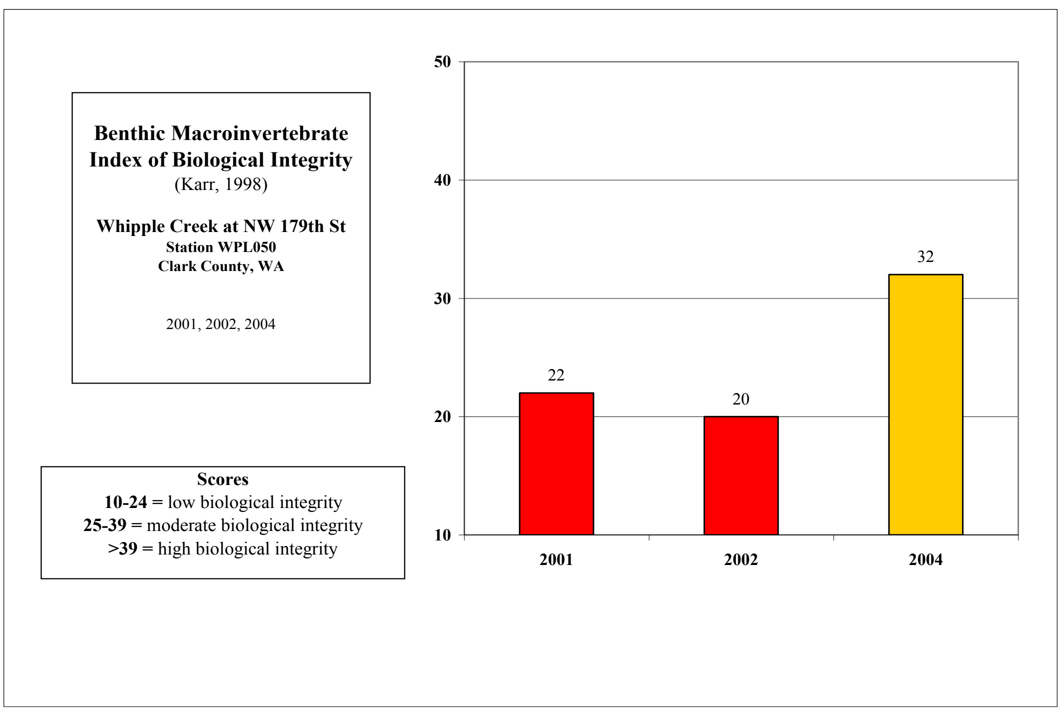

Figure 6. B-IBI scores for Whipple Creek station WPL050, 2001, 2002, and 2004.

B-IBI scores in 2001 and 2002 indicated low biological integrity. In 2004, the score improved into the moderate range. Given only three years of data, it is unknown whether the improvement in 2004 is indicative of a larger trend or simply the result of short-term variations in weather or local conditions. Regardless, the available data suggest that biological integrity in Whipple Creek is substantially degraded.

In addition to the overall B-IBI scores, individual metric scores may give insight into stream conditions and better explain differences in the overall score. King County provides a basic description of each B-IBI metric and these are paraphrased below. For a full description see http://dnr.metrokc.gov/wlr/waterres/Bugs/metrics_desc.htm.

Total taxa richness: The total number of taxa collected. Stream biodiversity declines as flow regimes are altered, habitat is lost, chemicals are introduced, energy cycles are disrupted, and alien taxa invade.

Mayfly (Ephemeroptera) taxa richness: The total number of mayfly species collected. Mayfly diversity declines in response to human influence. Many graze on algae. They are sensitive to chemical pollution that interferes with algae growth, but may increase in diversity over stoneflies and caddisflies in cases of high nutrient enrichment.

Stonefly (Plecoptera) taxa richness: The total number of stonefly species collected. Stoneflies are the first to disappear as human disturbance increases. Many are predators that depend on hiding between rocks- these types are very sensitive to sediment pollution. Others are shredders that rely on leaf litter from overhead tree canopies. Most require cool water and high dissolved oxygen levels.

Caddisfly (Trichoptera) taxa richness: The total number of caddisfly species collected. Caddisflies are a diverse group including some sensitive and some tolerant taxa representing many functional feeding groups (scrapers, collectors, predators). Taxa richness tends to decline as stream habitat becomes less varied and complex.

Intolerant taxa richness: These are the most sensitive taxa, representing approximately 5-10% of the taxa present in a region. They are the first to disappear as disturbance increases.

Clinger taxa richness: These taxa are adapted to hold onto smooth substrates in fast water. Because they occupy the open area between rocks, they are particularly sensitive to fine sediment.

Long-lived taxa: These taxa require more than one year to complete their life cycles, thus they are exposed to all the human activities that might influence the stream over a lengthy period. These taxa may disappear from streams that run dry during part of the year or experience on-going cyclical problems that interfere with their life cycles.

Percent tolerant: Tolerant taxa are present at most stream sites, but as disturbance increases they will represent an increasingly large percentage of the population. Tolerant species represent the 5-10% most tolerant taxa in a region. They are the opposite end of the spectrum from intolerant taxa.

Percent predator: Predators are the peak of the food web and depend on a reliable source of other invertebrates they prey on. The percentage of predator taxa provides a measure of the trophic complexity supported by a site.

Percent dominance (3 taxa): As diversity declines, a few taxa will begin to dominate the population. More tolerant or opportunistic species will replace sensitive or specialized species as habitat becomes more limited. This metric is calculated by adding the individuals in the three most common taxa and dividing by the total number of individuals in the sample.

Figure 7 shows the individual metric scores for each year.

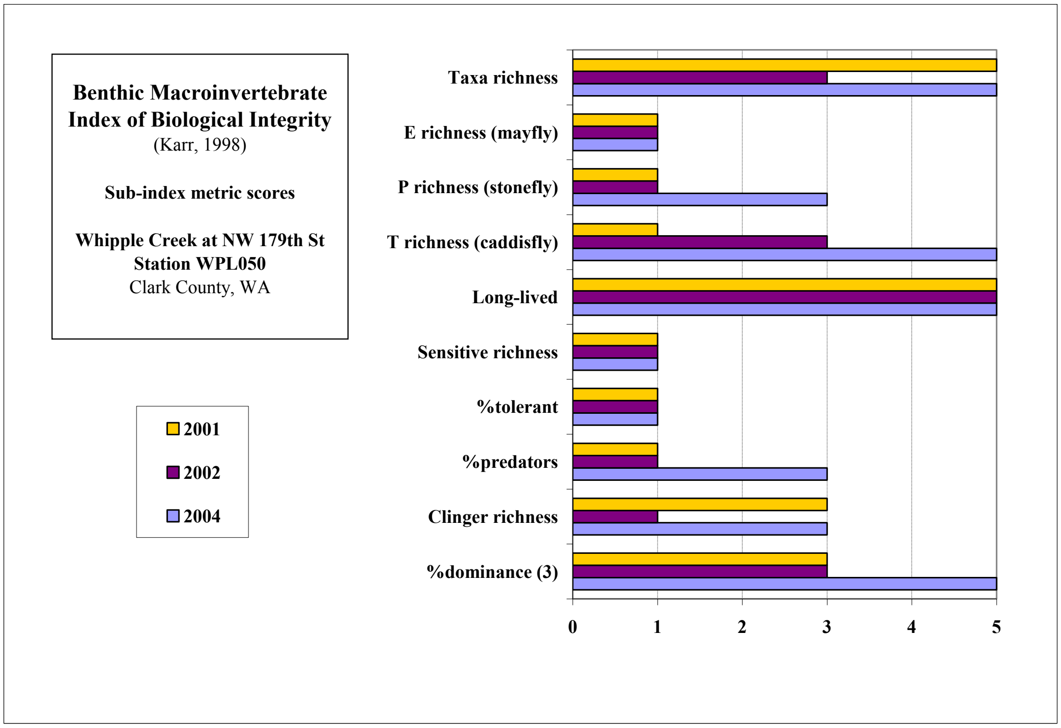

Figure 7. B-IBI metric scores for station WPL050, 2001, 2002, and 2004.

Overall taxa richness has remained moderate to good, as has the number of long-lived species. Beyond these two metrics, there is less good news. Although a substantial increase in caddisfly richness (6 taxa) and a slight increase in stonefly richness (2 taxa) is encouraging, we do not see a similar increase in some other critical metrics. Notably, the scores for sensitive richness and percent tolerant species are uniformly low, indicating few sensitive species and a dominance by pollution tolerant taxa. The percent dominance score in 2004 reflects a slight increase in diversity.

Predator species increased in 2004, in keeping with the increases in stonefly and caddisfly species, as well as the overall increase in diversity. Clinger species richness varied widely in the past several years. As a measure of sediment pollution, the variability in clinger richness likely reflects the unstable nature of the stream substrate. In some years sediment may be washed away to expose increased gravel substrate, while in other years these habitats are covered up.

It should be noted that many of the metric scores for Whipple Creek are very near B-IBI category thresholds and could readily rise or fall to another category. Differences as little as a single taxon would be enough to change a metric score in some cases.

Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (Hilsenhoff, 1988) summarizes the overall pollution tolerances of the taxa collected. Although it was originally developed to detect organic pollution, this index has also been used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. A family level HBI is calculated for each sample. Samples with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 polluted. (BLM/USU National Aquatic Monitoring Center (http://www.usu.edu/buglab).

For 2002 and 2004, HBI scores for WPL050 were 4.31 and 4.55, respectively, indicating slight to moderate nutrient enrichment. These results are consistent with the elevated nutrient levels routinely detected in water quality samples.

Implications for stormwater management

Macroinvertebrate sampling is conducted on riffle habitat within a single 500-foot reach toward the lower end of the 10-mile Whipple Creek mainstem. Results may not be indicative of the entire stream. However, the cumulative result of upstream land use and management has an impact on conditions at the sampling station. The low to moderate biological integrity indicated by samples from WPL050 suggests that human influence on Whipple Creek has been substantial.

The B-IBI scores reflect impacts to habitat complexity and stability. Based on metric scores and our existing knowledge of water quality conditions, the impacts to benthic macroinvertebrate populations are likely attributable largely to altered flow regimes and sediment accumulation. Elevated stream temperatures are a known problem and may also be impacting some of the more sensitive taxa. The potential presence of toxins in the sediment or water column could also have an impact, particularly on sensitive taxa and overall taxa richness.

In addition to stabilization of flow regimes, stormwater projects that focus on controlling turbidity, total solids, and temperature as listed in Table 3 are likely to have the most positive impact on biological integrity in Whipple Creek. Should toxins prove to be an issue, projects or management activities designed to reduce pesticides and other toxins would be appropriate.

Physical Habitat

EMAP survey

Water Resources collected quantitative habitat measurements for a 500-ft reach immediately upstream of the Sara intersection (NW179th Street and NW 41st Ave) during 2002. The assessment utilized methods described in the USEPA Environmental Monitoring and Assessment Program (EMAP) Western Pilot Study: Field Operations Manual for Wadeable Streams (Peck et al., eds. 2001) and was performed as part of Water Resources' Long-term Index Site Project (LISP). For additional detail, see the Long-term Index Site Monitoring Project: 2002 Physical Habitat Characterization report (Schnabel, 2003) on the county website at http://www.clark.wa.gov/water-resources/documents.html.

EMAP physical habitat protocols are designed for monitoring applications where robust, quantitative descriptions of reach-scale habitat are desired, such as site classification, trend interpretation, and analysis of possible causes of biotic impairment (Peck et al., 2001). They are designed to collect quantifiable measurements about general physical habitat attributes important in influencing stream ecology. Table 4 summarizes a number of indices and metrics derived from the EMAP data and provides a brief characterization of the site based on each metric.

Based on a habitat quality index that includes metrics for channel complexity, substrate composition, fish cover, and canopy density, Whipple Creek scored considerably below an Oregon DEQ grade-C reference stream. Grade "C" sites are the lowest grade of sites that qualify for use as a reference site, and are only used when a less impacted site is not available (Drake, 2003 draft). They exhibit marginally functional watershed and stream conditions, with obvious human disturbance. Given this criterion, the Whipple Creek index score indicates a highly disturbed system.

Table 4. Summary of Habitat Metrics in Whipple Creek EMAP reach near Sara.

Habitat category	Index or metric	Result	Characterization
Overall habitat quality	Habitat quality index (HQI)[1]	71	Score is relative to a DEQ grade-C reference condition scoring 100 on a normalized scale[2]
Overall riparian quality	QR1 index[3] RCOND index[4]	0.70 0.68	Good Good
Hydrologic flashiness	Mean of 3 indices[4]	4.13	Obvious hydrologic impact
Channel morphology	Pool percentage (PCT_POOL) Riffle percentage (as PCT_FAST)	27% 19%	Does not meet recommended pool area[5] Does not meet recommended riffle area[5]
Substrate composition	Dominant substrate Mean embeddedness (XEMBED) Substrate sand and fines (PCT_SAFN) D_{50} (median particle size, mm)	61% 86% 46% 1.2	Fine gravel and smaller (<=16mm) "Not properly functioning"[6] "Not properly functioning"[6] (22% fines <0.6mm, 25% sand (0.6-2mm) n/a
Bed substrate stability	Bed stability (LRBS_BW4)	-1.63	Streambed relatively unstable[7]
Fish cover	Natural fish cover by area (XFC_NAT)	0.52	Fish cover relatively abundant
Large woody debris	Total LWD density (C1W)	401/mile	"Not properly functioning"[6] (good density but not large enough)
Riparian vegetation cover	Stream shading (XCDENMID)	73%	Moderately shaded
Invasive plant species	Overall invasive plant proportion (individual species proportion)	1.27	Invasive plants common (English Ivy = 0.09, Him Black = 0.55, Reed Canary = 0.64)

[1]developed by Glen Merritt, Washington Department of Ecology
[2]Drake, 2003 draft, Oregon Department of Environmental Quality
[3]Dr. Philip Kaufmann,USEPA; Butkus, 2002
[4]Dr. Philip Kaufmann, USEPA
[5]Peterson et al., 1992; WDFW and Western Washington Treaty Tribes 1997; WDNR 1997
[6]National Marine Fisheries Service (NMFS) Matrix of Pathways and Indicators, 1996
[7]Kaufmann, et al., 1999

There were a few bright spots in the assessment. Overall riparian quality was good based on two multi-metric indices, fish cover was relatively abundant, and riparian shading was relatively good at 73%. However, these metrics are site-specific and do not necessarily integrate or reflect watershed-wide conditions.

For most other metrics, including those that integrate impacts from the upstream watershed, Whipple Creek fell short of desired conditions. Whipple Creek was among the most "flashy" of 10 streams assessed in Clark County during 2002. "Hydrologic flashiness" is an indication of the tendency of a stream to exhibit extremes in flow regime. Storm hydrographs from a "flashy" stream are often much steeper and of shorter duration than normal. Flashiness is often associated with streams in watersheds having large amounts of impervious surface area or cleared land, as stormwater volumes tend to increase and runoff reaches the stream more quickly.

Conversely, a flashy stream may exhibit very low flows during dry weather due to lack of groundwater recharge during wet weather. Because flashy streams often have wide channels that have been scoured by storm flows, summer baseflow may only fill a fraction of the channel.

Channel morphology was dominated by glide habitat, with far fewer pools and riffles than recommended. Substrate was dominated by sand, silt, and fine gravels, with a high level of embeddedness and a very small median particle size. As a result, the streambed is relatively unstable in the assessed reach. The bed stability metric compares the size range of streambed material with the stream's erosive capability. If most of the streambed sediments are finer than the size the stream is capable of moving, then the streambed is relatively unstable.

Total Large Woody Debris (LWD) density was relatively high at a frequency of 401 pieces/mile in the assessed reach. However, most pieces were not large enough to qualify as high quality wood. Invasive plants were dominant throughout the reach, particularly Himalayan blackberry and Reed Canary grass.

Implications for stormwater management

The EMAP assessment was performed on a single 500-foot reach toward the lower end of the 10-mile Whipple Creek mainstem. Results may not be indicative of the entire stream. However, the cumulative result of upstream land use and management is a highly disrupted and unstable stream channel at the assessment site.

From a stormwater perspective, the unstable streambed, high level of "flashiness", fine-grained and highly embedded substrate, and modified channel morphology indicate significant challenges. These metrics indicate that Whipple Creek is subject to higher flows than it can handle effectively, and carries a significant amount of silt and sediment.

Overall, the EMAP metrics suggest that stormwater projects and watershed activities that help stabilize flow regime and control channel erosion could lead to localized improvements in stream habitat. However, due to the complexity and extent of influences on hydrologic condition, it is difficult to predict whether stormwater projects alone can have a substantial impact on watershed-wide habitat quality.

Data gaps and potential monitoring projects

The data set for monitoring station WPL050 will continue to grow as the Long-term Index Site Project is implemented. Within the next five years, monthly water quality and annual benthic macroinvertebrate data sets will begin to indicate trends in condition. Over the long term, this station will provide a reliable measure of the cumulative impact of upstream management activities. Data of this type will provide us with the means to answer the questions "Is overall water quality improving or degrading?", and "What is the rate of change in water quality?"

Long-term stations such as WPL050 are intended to integrate water quality impacts from a large portion of the watershed and provide a measure of cumulative impacts from upstream activities. However, they provide little or no spatial detail regarding water quality conditions in upstream areas. Additional studies are required if a more spatially dense information set is needed.

Table 5 lists potential monitoring activities and their purpose. Given existing water quality knowledge and ongoing monitoring, the list of potential future monitoring projects is relatively brief. For the most part, existing data gaps are spatial rather than characteristic-based. The exception is the potential for toxics or metals contamination in sediments. We have no knowledge of the quality of sediments in Whipple Creek, a question of some concern given the large amount of stormwater runoff and sediment accumulation. Toxics and metals in high concentrations could have significant impacts on both recreational and fish-related beneficial uses.

Staff have discussed the idea of sampling toxics or metals in sediment behind flow control structures, such as beaver dams, especially in areas below major features such as the I-5 corridor or heavily commercialized areas. Sediments may show an impact that is not detected by sampling more transient water quality variables monthly or even during storms.

Increased spatial density for some characteristics is worth considering, particularly stream temperature, fecal coliform bacteria, and benthic macroinvertebrates. However, the need for these studies will be contingent on the overall goals of the Whipple Creek Watershed Projects Plan and other programmatic priorities. For instance, increased knowledge of stream temperatures may be necessary if fish recovery is a priority for future Whipple Creek management. Conversely, if the priority is increased public access and the development of stormwater facilities to serve as park-like amenities, then stream temperatures are less critical while detailed information about bacteria concentrations and sources may be beneficial.

Table 5. Data gaps and potential monitoring projects

Characteristic	Data gap	Possible monitoring projects	Comment
Fecal coliform	Spatial distribution of bacteria	Short-term (1-2 yr) multiple station	Defines bacteria source areas for further investigation, education, or projects
	Specific bacteria sources	Same as above plus: Illicit Discharge screening project; stormwater monitoring; Bacterial Source Tracking (e.g. ribo-typing)	Locates specific sources for removal or control; helps define source types (e.g. human, beaver, horse)
Stream temperature	Spatial distribution and source reaches	Continuous summer temperature loggers at multiple locations	Defines areas contributing to higher temperatures and locates reaches with intact thermal refuge
Benthic macroinvertebrates	Spatial distribution of habitat condition	Short-term (1-2 yr) multiple station	Locates areas of high-quality riffle habitat; better defines extent of habitat degradation
Toxics/Metals	No current knowledge	Short-term (1 yr) multiple station sediment analysis	Determines presence of toxics or metals; defines potential beneficial use impacts

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